(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(54) Title: COMBINED RADIAL-AXIAL SLIDE BEARING
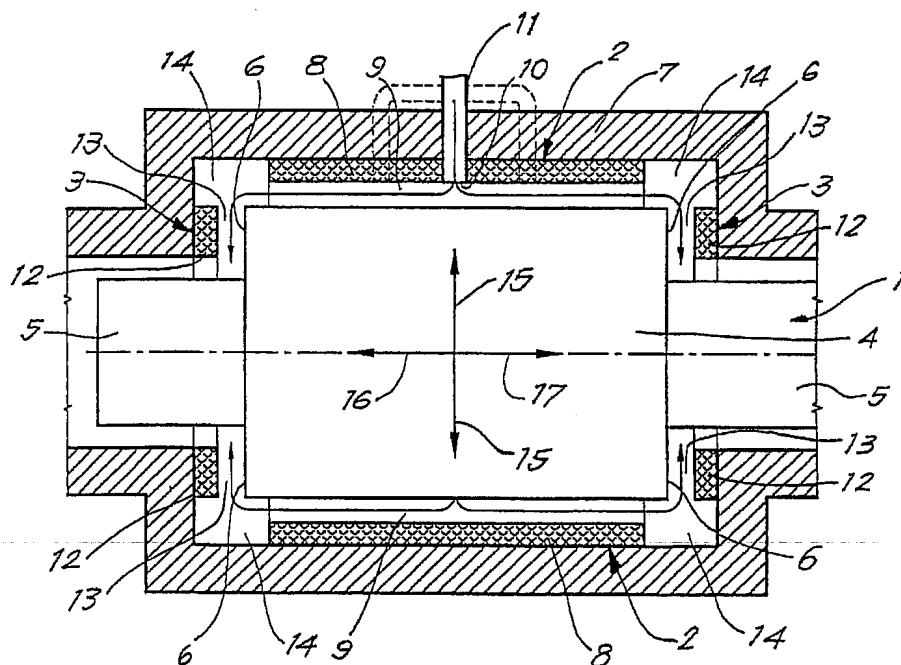
(57) Abstract: The slide bearing is constructed of, on one hand, a hydrodynamic radial slide bearing (2) which surrounds, with a play, an axle (1) to be beared, such that between the axle (1) and the radial slide bearing (2), a first gap (9) is formed which is in connection with a source of liquid under pressure and, on the other hand, at least one hydrostatic axial slide bearing (3) which is situated with a play opposite to a radially extending surface portion (6) of the axle (1), such that also between this portion (6) of the axle (1) and a radially directed portion (12) of the axial slide bearing (3), a second gap (13) is formed which is in connection with the first gap (9).

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Combined radial-axial slide bearing.

This invention relates to a combined radial-axial slide
5   bearing.

A possible form of a liquid-lubricated axial slide
bearing is a hydrostatic bearing whereby use is made of
an external power source supplying the liquid under
10   pressure to the slide bearing.

This liquid is brought into the bearing by means of a
flow restrictor or restrictor, such as a capillary or a
small opening.
15

The principle of such hydrostatic bearing is based on the
fact that, when the gap of the bearing becomes smaller,
the flow diminishes and the pressure drop over the
restrictor is reduced. The pressure in the gap increases,
20   and the force which caused the gap to narrow is
compensated.

These hydrostatic bearings have a high loading capacity
depending on the feeding pressure of the liquid, a high
25   stiffness and a carrying capacity which is little
dependent on the number of revolutions.

Especially if the lubricating liquid has a low viscosity,
such as water, this restrictor, however, has to be very
30   small, as a result of which this latter becomes very
sensitive to obstructions.

In such bearing, the tolerances are very narrow,
especially with water, in consideration of the fact that,
35   in order to limit the flow rate, the gap of the bearing
has to be as small as possible.

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Moreover, due to this restrictor, the construction of the axial bearing is rather complex and this bearing is expensive, whereas in most cases a pump has to be applied in order to obtain sufficient pressure.

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One of the forms of a radial slide bearing lubricated with a liquid is the hydrodynamic bearing, whereby the movement of the axle itself provides for the necessary pressure of the lubricating liquid.

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The bearing surrounds the axle with a little play in between. When a radial force effects on the axle, the axle will situate itself excentrical, as a result of which a wedge is formed. Under the influence of the revolving movement of the axle, the liquid is pressed into this natural narrowing, as a consequence of which a pressure build-up is resulting. This pressure build-up will lift the axle and provide for that the force which displaced the axle is counteracted. Thus, it is so that in balance, the axle will not be centered, as otherwise no pressure could be build up. Ideally, the excentricity is between 60% and 90%.

Such hydrodynamic bearings are rather simple and inexpensive, although they require narrow manufacturing tolerances. They are operationally reliable, however, they have no high loading capacity and rigidity. It is, however, disadvantageous that their loading power depends on the number of revolutions and that, during starting, there is a contact between the axle and the bearing and therefore wear and tear does occur.

It is, however, also known to combine a hydrostatic axial and a hydrostatic radial bearing to a single slide bearing.

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Such combined radial-axial slide bearing is described,
amongst others, in the British patent No. 639.293.

An axle which is provided with two collars in between
5   which a stationary ring with a small play is provided and
which is provided with a number of recesses in its inter-
nal circumference, at which, by means of a restricting
mouthpiece, a restrictor is formed and to which a fluid,
such as air or steam, is supplied.
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This fluid flows through the recesses up to the collar
and thus forms a fluid layer around the axle, such that
this latter is radially beared. This fluid flows radially
outward through the gap formed by the play between the
15   extremities of the ring and the collar and prevents the
contact between the ring and the collar or, in other
words, provides for the axial bearing.

In fact, the aforementioned British patent describes a
20   hydrostatic radial bearing which is fed by means of
several narrowings feeding to different chambers around
the bearing. Instead of feeding the hydrostatic axial
bearing by means of a separate narrowing, use is made of
the narrowing which is formed by providing the narrowing
25   of the radial bearing in series with the radial bearing
itself.

Due to the presence of the mouthpieces forming a narrow-
ing or restrictor, this known combined bearing, however,
30   possesses the same disadvantages as the aforementioned
axial bearings, with thus, amongst others, the danger of
obstruction of these narrowings.

The invention aims at a combined radial-axial slide
35   bearing which does not show these disadvantages and
therefore causes no danger of obstruction of a capillary

or mouthpiece and which is relatively inexpensive and compact.

According to the invention, this aim is achieved in that the combined bearing is composed of, on one hand, a hydrodynamic radial slide bearing which surrounds an axle to be beared with a play, such that between the axle and the radial slide bearing, a first gap is formed, which first gap is in connection with a source of liquid under pressure and, on the other hand, at least one hydrostatic axial slide bearing which, with a play, is situated opposite to a radially extending surface portion of the axle, such that also between this last-mentioned surface portion of the axle and a radially-directed portion of the axial slide bearing, a second gap is formed, whereby this second gap is in connection with the first gap, such that this axial slide bearing is fed by means of the first gap and this first gap fulfils the function of restrictor for the axial slide bearing.

In that the first gap takes the function of restrictor for the axial slide bearing, no external restrictor is required, such that all above-mentioned disadvantages, which are a consequence of such external resistor, are eliminated.

The first gap and the second gap do not necessarily have to be in direct connection with each other. They can do so by means of a chamber between the axle and a bearing housing.

A portion of this housing can border the gaps directly. The housing can be provided also at the inside with one or more bearing cushions or such, which border a gap.

The combined bearing can be singular and comprise a

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single axial slide bearing at an extremity of the radial
bearing, whereby, thus, the second gap is in connection
with one extremity of the first gap, however, in a
variant this combined bearing is double-sided and
5   comprises two axial slide bearings, one at each extremity
of the radial slide bearing, whereby the second gaps of
the two axial slide bearings are in connection with
respectively the two extremities of the first gap.

10   In this latter case, the connection of the first gap to
the source of liquid under pressure preferably gives out
in the center of the first gap on two locations which are
situated symmetrical in respect to the middle of the
first gap.

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In the other case with one axial bearing, the afore-
mentioned connection can give out at any location in the
first gap, whereby the pressure drop in this gap for one
and the same flow rate of liquid depends on the position
20   of this location.

With the intention of better showing the characteristics
of the invention, hereafter, by way of example without
any limitative character, two preferred forms of embodi-
25   ment of a combined radial-axial slide bearing according
to the invention are described, with reference to the
accompanying drawings, wherein:

figure 1 schematically represents a cross-section of
30   an axle beared by means of a combined slide bearing
according to the invention;

figure 2 schematically represents a cross-section
according to that from figure 1, however, in respect
to another form of embodiment of the combined slide
35   bearing according to the invention.

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In figure 1, an axle 1 or, more specifically, an
extremity of this axle 1 is represented which is beared
radially and axially in a water-lubricated combined
radial-axial slide bearing 2-3.

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This axle 1 is fixed, for example, to one of the rotors
of a water-lubricated compressor element and, in respect
to the axial mode of bearing, shows an abrupt alteration
of diameter.

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It therefore comprises a portion 4 with a larger diameter
and a portion 5 having a smaller diameter and forming the
free extremity, such that in between these portions 4 and
5, a radially-directed shoulder or, in other words, a
15   radially-directed surface portion 6 is formed.

The combined slide bearing 2-3 substantially consists of
a hydrodynamic radial slide bearing 2 surrounding the
portion 4 with the largest diameter, and of a hydrostatic
20   axial slide bearing 3, which are formed in a bearing
housing 7.

The radial slide bearing 2 comprises a bearing cushion 8
surrounding the portion of the axle 1 with a play, such
25   that in between them, a first narrow gap 9 is created.

The mouth 10 of a supply conduit 11, extending through
the slide bearing 2, for water under a pressure P_{in},
which conduit is connected to a source of water under
30   pressure not represented in figure 1, for example the
conduit with water for the injection onto the rotors of
the compressor, gives out onto this gap 9.

This hydrodynamic radial slide bearing 2 has been calcu-
35   lated according to known standard methods, for example,
the method of Summerfeld as described, amongst others, in

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"Machine-onderdelen" by Roloff/Matek, p. 450-473, whereby
the operating conditions, the building-in possibilities,
the applied lubricant, which, in the given example, is
water, have been taken into consideration.

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The axial slide bearing 3 comprises a ring-shaped bearing
cushion 12 which is fixed opposite to the aforementioned
radial surface portion 6 of the axle 1 against an also
radially-directed portion of the interior wall of the
10   bearing housing 7, whereby in between this bearing
cushion 12 and the surface portion, a second gap 13 is
formed. This bearing cushion 12 thus forms a radially-
directed portion of the slide bearing 3.

15   This second gap 13 is in connection with the aforemen-
tioned first gap 9, by means of a ring-shaped closed
chamber 14 which is formed in between the two bearing
cushions 8 and 12, between the interior side of the
bearing housing 7 and the axle 1.

20

This axial bearing 3, too, has been calculated according
to standard methods for hydrostatic axial slide bearings
which are fed by a restrictor, such as, amongst others,
described in "Machine-onderdelen" by Roloff/Matek, p.
25   473-479, however, with the difference that instead of the
diameter of an opening or capillary, the distance from
the aforementioned mouth 10 in the first gap 9 up to the
chamber 14 at the extremity of this gap 9 is used as a
parameter.

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In this classic calculation, the equation for calculating
the pressure drop over the restrictor is replaced by an
equation describing the pressure drop in the assembly
described heretofore. The pressure drop over the bearing
35   can be calculated in a simplified manner by means of the
following equation:

$$\Delta P = Q.12 \text{ visco}.L/(0,5 \ S)^3.\Pi.D$$

wherein:

Q = flow rate

visco = viscosity of the medium

L = distance from the openings up to the edge of the bearing

D = diameter of the radial bearing

S = diametrical play of the radial bearing

ΔP = pressure drop over the bearing: $P_{in} - P_{ax}$.

The functioning of the combined slide bearing 2-3 is as follows:

The radial slide bearing 2 normally functions as a hydrodynamic bearing, this means that the liquid which is fed into the gap 9 under the pressure P_{in} forms a ring-shaped layer under the influence of the rotation of the axle 1, whereby thus the axle is lifted up into balance position, as represented in figure 1 by arrows 15. In this balance position, the axle 1 is not centered in the radial bearing 2.

The axial slide bearing 3 is fed by water which is flowing from the mouth 10 in the first gap 9 of the radial slide bearing 2. As this gap 9 is very narrow, a pressure drop ΔP, which is equal to the flow rate, is created over the traject between this mouth 10 and the chamber 14.

In this chamber 14, and thus also at the entry of the second gap 13 of the hydrostatic axial slide bearing 3, a pressure $P_{ax} = P_{in} - \Delta P$ is prevailing.

Due to the pressure build-up during operation, the rotor

and therefore also the axle 1 shall be pushed axially into the direction. The axial forces on the axle 1 are indicated in figure 1 by arrow 16.

5 As a consequence of these axial force, the axle 1 will be inclined to move into the direction of arrow 16. When, however, the width of gap 3 diminishes, the water flow rate through this gap 13, but also through the first gap 9 will diminish, as a result of which the pressure drop
10 ΔP diminishes.

From the aforementioned equation can be deduced that as a result of this, the pressure P_{ax} increases, which has as a consequence that the aforementioned axial force is
15 counteracted until a balance is obtained.

When the axial force drops under this balance, the width of the gap 13 will increase, as a result of which the water flow rate increases and the pressure drop ΔP is
20 enlarged. Hereby, also the pressure P_{ax} diminishes until a balance is obtained again.

Thus, the first gap 9 takes over the roll of opening or capillary for the axial slide bearing 3.
25
It is clear that the pressure drop ΔP depends on the length of the portion of the gap 9 between the mouth 10 and the chamber 14. In figure 1, this mouth 10 is repre-sented in the center of the gap 9, however, by moving
30 this mouth 10 towards the axial slide bearing 3 or away from this slide bearing 3, this pressure drop ΔP, with a same flow rate, will diminish, increase, respectively.

When calculating the axial slide bearing 3, it is
35 provided for that, if the width of gap 13 is minimum, which depends on the stroke and the angularity of the

axial slide bearing 3 and on the roughness of the surfaces, the pressure P_{ax} is as high as possible and, as a consequence, the pressure drop ΔP is minimum. However, there still must be a water flow rate which is large
5 enough to dissipate the frictional heat.

With a maximum width of the gap 13, which may not be too large, the aforementioned pressure P_{ax} has to be as low as possible and, as a consequence, the pressure drop ΔP
10 has to be maximum.

The form of embodiment represented in figure 2 differs from the form of embodiment described heretofore in that the combined bearing 2-3 is double-sided, this means, it
15 can take up axial forces as well in the direction indicated by arrow 16 as in the opposite direction, represented by arrow 17 in figure 2, and to this aim comprises, apart from one radial slide bearing 2, two axial slide bearings 3 which are identical to the
20 bearings 2, 3 respectively, described heretofore.

The axle 1 comprises two portions 5 with smaller diameter, whereby thus between the thicker portion 4 and each of the portions 5 a shoulder is formed and thus a
25 radially-directed surface portion 6, opposite to which an axial bearing 3 is situated.

By means of a chamber 14, the gaps 13 of the two radial slide bearings 3 are connected to respectively both
30 extremities of the gap 9 of the radial slide bearing 2.

The water which is fed into the gap 9 at the pressure P_{in} splits up into two flows with a well-defined flow rate, one towards each gap 13.
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The radial slide bearing 2 functions as in the form of

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embodiment according to figure 1. Also the two axial
slide bearings 3 function in the same manner as described
heretofore, whereby, however, the width of the one gap 13
diminishes when the width of the other increases, and
5   reverse.

Usually, the mouth 10 in the middle between the two axial
slide bearings 3 is chosen and these latter equal to each
other, such that in balance position, the two gaps 13
10 will be equally wide and the flow rates towards these
gaps 13 will be equal. As soon as there is a deviation
from this balance, one flow rate shall be higher than the
other, as a result of which the pressures P_{ax} will be
different and the too large axial pressure will be
15 counteracted.

In a variant, the supply conduit 11 is splitting into two
at the extremity, and there are thus two mouths 10 which,
as is represented in dashed line in figure 2, give out in
20 the gap 9 symmetrically in respect to the middle between
the two axial slide bearings 3.

The liquid brought into the gap 9 by means of the supply
conduit 11 not necessarily has to be water. It may, for
25 example, also be oil or another lubricating liquid.

The gaps 9 and 13 do not necessarily have to be in
connection by means of a chamber 14. Possibly, they can
directly be connected to each other.
30

The invention is in no way limited to the forms of
embodiment described heretofore and represented in the
figures, on the contrary may such combined radial-axial
slide bearing be realized in different variants without
35 leaving the scope of the invention.

Claims.
_____

1.- Combined radial-axial slide bearing, characterized in
that it it composed of, on one hand, a hydrodynamic
radial slide bearing (2) which surrounds an axle (1) to
be beared with a play, such that between the axle (1) and
the radial slide bearing (2), a first gap (9) is formed,
which first gap (9) is in connection with a source of
liquid under pressure and, on the other hand, at least
one hydrostatic axial slide bearing (3) which, with a
play, is situated opposite to a radially extending
surface portion (6) of the axle (1), such that also
between this last-mentioned surface portion (6) of the
axle (1) and a radially-directed portion (12) of the
axial slide bearing (3), a second gap (13) is formed,
whereby this second gap (13) is in connection with the
first gap (9), such that this axial slide bearing (3) is
fed by means of the first gap (9) and this first gap (9)
fulfils the function of restrictor for the axial slide
bearing (3).

2.- Combined radial-axial slide bearing according to
claim 1, characterized in that the first gap (9) and the
second gap (13) are in connection with each other by
means of a chamber (14) between the axle (1) and a
bearing housing (7).

3.- Combined radial-axial slide bearing according to
claim 1 or 2, characterized in that it is singular and
comprises one axial slide bearing (3) at an extremity of
the radial bearing (2), whereby thus the second gap (13)
is in connection with one extremity of the first gap (9).

4.- Combined radial-axial slide bearing according to
claim 1 or 2, characterized in that it is double-sided

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and comprises two axial slide bearings (3), one at each extremity of the radial slide bearing (2), whereby the second gaps (13) of the two axial slide bearings (3) are in connection with respectively the two extremities of

5   the first gap (9).

5.- Combined radial-axial slide bearing according to claim 4, characterized in that the connection of the first gap (9) with the source of liquid under pressure

10   gives out in the center of this gap (9).

6.- Combined radial-axial slide bearing according to claim 4, characterized in that the connection of the first gap (9) with the source of liquid under pressure

15   give out on two locations which are symmetrically in respect to the center of this gap (9).

7.- Combined radial-axial slide bearing according to any of the preceding claims, characterized in that the

20   connection of the first gap (9) with the source of the liquid under pressure comprises a supply conduit (11) with a mouth (10) extending through the radial slide bearing (2).

25   8.- Combined radial-axial slide bearing according to any of the preceding claims, characterized in that the radial slide bearing (2) as well as the axial slide bearing (3) comprise a bearing cushion (8, 12).

30   9.- Combined radial-axial slide bearing according to any of the preceding claims, characterized in that the axle (1) is the axle of a rotor of a compressor.

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Fig.1

Fig.2
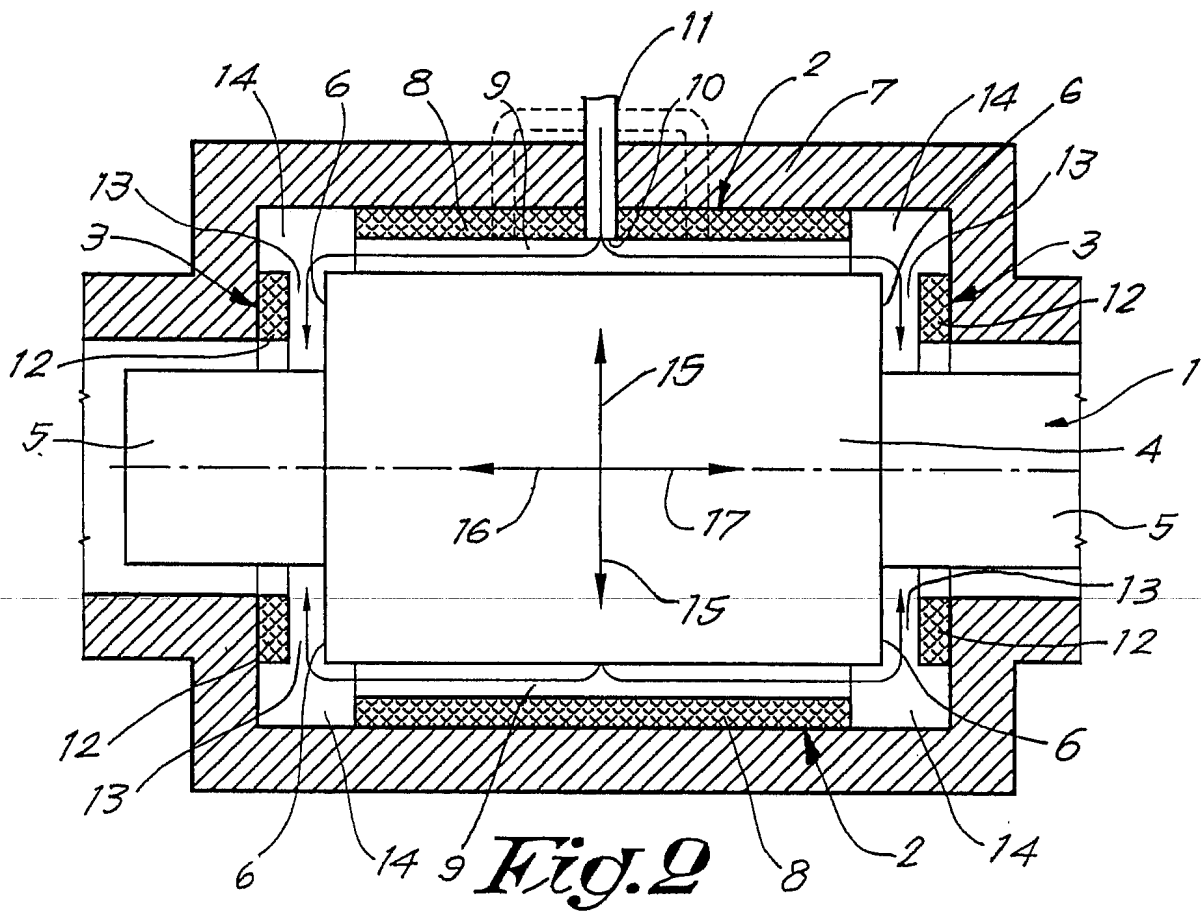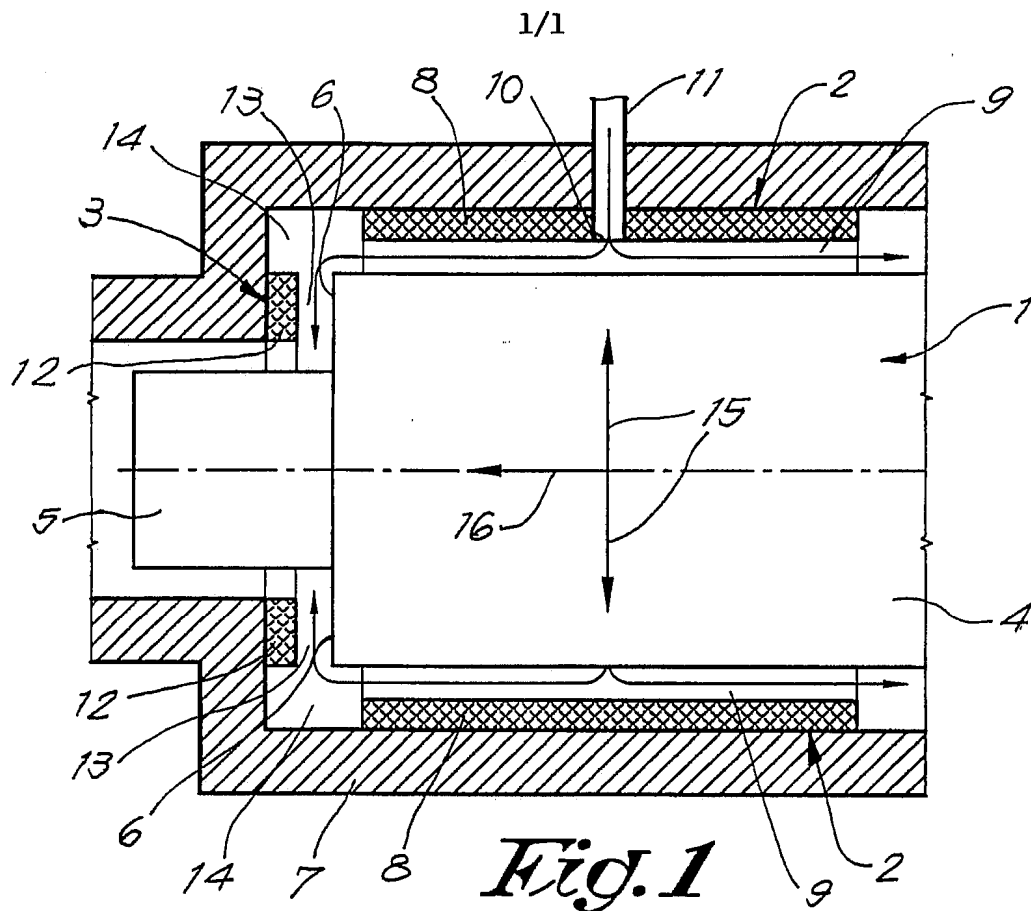
A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   F16C32/06   F16C33/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7   F16C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 2 084 515 A (ATOMIC ENERGY AUTHORITY UK) 17 December 1971 (1971-12-17) page 2, line 29-33; figure 1 page 3-4 ---	1
A	US 4 090 743 A (SUZUKI HIROSHI ET AL) 23 May 1978 (1978-05-23) ---	
A	US 4 438 339 A (MCHUGH JAMES D) 20 March 1984 (1984-03-20) -----	

☐ Further documents are listed in the continuation of box C.   ☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
19 October 2000	27/10/2000

Name and mailing address of the ISA	Authorized officer
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